IN THE SPECIFICATION:

Please replace paragraphs [0005], [0027], [0028], [0029], [0031], [0032], [0033], [0034], [0035], [0037], [0038], [0039], [0040], [0041], [0042], [0043], [0045], [0046], [0047], [0048], [0049], [0050], [0051], [0054], [0055], [0059], [0060], [0061], [0062], [0063], [0068], and [0070] with the following amended paragraphs:

[0005] Atomic layer deposition is one deposition technique being explored for the deposition of material layers over features having high aspect ratios. One example of atomic layer deposition comprises the sequential introduction of pulses of gases. For instance, one cycle for the sequential introduction of pulses of gases may comprise a pulse of a first reactant gas, followed by a pulse of a purge gas and/or a pump evacuation, followed by a pulse of a second reactant gas, and followed by a pulse of a purge gas and/or a pump evacuation. The term "gas" as used herein is defined to include a single gas or a plurality <u>of</u> gases. Sequential introduction of separate pulses of the first reactant and the second reactant may result in the alternating self-limiting absorption of monolayers of the reactants on the surface of the substrate and, thus, forms a monolayer of material for each cycle. The cycle may be repeated to a desired thickness of the deposited material. A pulse of a purge gas and/or a pump evacuation between the pulses of the first reactant gas and the pulses of the second reactant gas serves to reduce the likelihood of gas phase reactions of the reactants due to excess amounts of the reactants remaining in the chamber.

[0027] The chamber 200 comprises a chamber body 202 having sidewalls 204 and a bottom 206. A slit valve 208 in the chamber 200 provides access for a robot (not shown) to deliver and retrieve a substrate 210, such as a 200 mm or 300 mm semiconductor wafer or a glass substrate, <u>to and</u> from the chamber 200.

[0028] A substrate support 212 supports the substrate 210 on a substrate receiving surface 211 in the chamber 200. The substrate support 212 is mounted to a lift motor 214 to raise and lower the substrate support 212 and a substrate 210 disposed thereon.

A lift plate 216 connected to a lift motor 218 is mounted in the chamber 200 and raises and lowers pins 220 movably disposed through the substrate support 212. The pins 220 raise and lower the substrate 210 over the surface of the substrate support 212. The substrate support 212 may include a vacuum chuck (not shown), an electrostatic chuck (not shown), or a clamp ring (not shown) for securing the substrate ~~212~~ 210 to the substrate support 212 during processing.

[0029] The substrate support 212 may be heated to heat a substrate 210 disposed thereon. For example, the substrate support 212 may be heated using an embedded heating element, such as a resistive heater (not shown), or may be heated using radiant heat, such as heating lamps (not shown) disposed above the substrate support 212. A purge ring 222 may be disposed on the substrate support 212 to define a purge channel 224 which provides a purge gas to a peripheral portion of the substrate 210 to prevent deposition thereon.

[0031] In one embodiment, the gas delivery apparatus 230 comprises a chamber lid 232. The chamber lid 232 includes an expanding channel 234 extending from a central portion of the chamber lid 232 and a bottom surface 260 extending from the expanding channel 234 to a peripheral portion of the chamber lid 232. The bottom surface 260 is sized and shaped to substantially cover a substrate 210 disposed on the substrate support 212. The expanding channel 234 has gas inlets 236A, 236B to provide gas flows from two similar pairs of valves 242A/252A, 242B/252B, which ~~. The gas flows from the valves 242A, 242B~~ may be provided together and/or separately.

[0032] In one configuration, valve 242A and valve 242B are coupled to separate reactant gas sources but are preferably coupled to the same purge gas source. For example, valve 242A is coupled to reactant gas source 238 and valve 242B is coupled to reactant gas source 239, and both valves 242A, 242B are coupled to purge gas source 240. Each valve 242A, 242B includes a delivery line 243A, 243B having a valve seat assembly 244A, 244B and each valve 252A, 252B includes a purge line 245A, 245B having a valve seat assembly 246A, 246B. The delivery line 243A, 243B is in

communication with the reactant gas source 238, 239 and is in communication with the gas inlet 236A, 236B of the expanding channel 234. The valve seat assembly 244A, 244B of the delivery line 243A, 243B controls the flow of the reactant gas from the reactant gas source 238, 239 to the expanding channel 234. The purge line 245A, 245B is in communication with the purge gas source 240 and intersects the delivery line ~~242A, 242B~~ 243A, 243B downstream of the valve seat assembly 244A, 244B of the delivery line ~~242A, 242B~~ 243A, 243B. The valve seat assembly 246A, 246B of the purge line 245A, 245B controls the flow of the purge gas from the purge gas source 240 to the ~~delivery line 243A, 243B~~ expanding channel 234. If a carrier gas is used to deliver reactant gases from the reactant gas source 238, 239, preferably the same gas is used as a carrier gas and a purge gas (i.e. an argon gas used as a carrier gas and a purge gas).

[0033] Each valve seat assembly 244A, 244B, 246A, 246B may comprise a diaphragm (not shown) and a valve seat (not shown). The diaphragm may be biased open or closed and may be actuated closed or open respectively. The diaphragms may be pneumatically actuated or may be electrically actuated. Examples of pneumatically actuated valves include pneumatically actuated valves available from Fujiken, Inc. and Veriflow, Corp. Examples of electrically actuated valves include electrically actuated valves available from Fujiken, Inc. Programmable logic controllers 248A, 248B may be coupled to the valves 242A, 242B to control actuation of the diaphragms of the valve seat assemblies 244A, 244B, 246A, 246B of the valves 242A, 242B. Pneumatically actuated valves may provide pulses of gases in time periods as low as about 0.020 seconds. Electrically actuated valves may provide pulses of gases in time periods as low as about 0.005 seconds. An electrically actuated valve typically requires the use of a driver coupled between the valve and the programmable logic controller.

[0034] Each valve 242A, 242B may be a zero dead volume valve to enable flushing of a reactant gas from the delivery line 243A, 243B when the valve seat assembly 244A, 244B ~~of the valve~~ is closed. For example, the purge line 245A, 245B may be positioned adjacent the valve seat assembly 244A, 244B of the delivery line 243A, 243B. When

the valve seat assembly 244A, 244B is closed, the purge line 245A, 245B may provide a purge gas to flush the delivery line 243A, 243B. In the embodiment shown, the purge line 245A, 245B is positioned slightly spaced from the valve seat assembly 244A, 244B of the delivery line 243A, 243B so that a purge gas is not directly delivered into the valve seat assembly 244A, 244B when open. A zero dead volume valve as used herein is defined as a valve which has negligible dead volume (i.e. not necessary zero dead volume.)

[0035] Each valve pair 242A/252A, 242B/252B may be adapted to provide a combined gas flow and/or separate gas flows of the reactant gas ~~238, 239~~ and the purge gas ~~240~~. In reference to valve pair 242A/252A, one example of a combined gas flow of the reactant gas ~~238~~ and the purge gas ~~240~~ ~~provided by valve 242A~~ comprises a continuous flow of a purge gas from the purge gas source 240 through purge line 245A and pulses of a reactant gas from the reactant gas source 238 through delivery line 243A. The continuous flow of the purge gas may be provided by leaving the diaphragm of the valve seat assembly 246A of the purge line 245A open. The pulses of the reactant gas from the reactant gas source 238 may be provided by opening and closing the diaphragm of the valve seat assembly 244A of the delivery line 243A. In reference to valve pair 242A/252A, one example of separate gas flows of the reactant gas ~~238~~ and the purge gas ~~240~~ ~~provided by valve 242A~~ comprises pulses of a purge gas from the purge gas source 240 through purge line 245A and pulses of a reactant gas from the reactant gas source 238 through delivery line 243A. The pulses of the purge gas may be provided by opening and closing the diaphragm of the valve seat assembly 246A of the purge line 245A ~~open~~. The pulses of the reactant gas from the reactant gas source 238 may be provided by opening and closing the diaphragm of the valve seat assembly 244A of the delivery line 243A.

[0037] In reference to Figure 3, each gas conduit 250A, 250B and gas inlet 236A, 236B may be positioned in any relationship to a longitudinal axis 290 of the expanding channel 234. Each gas conduit 250A, 250B and gas inlet 236A, 236B are preferably positioned normal (in which $+\beta, -\beta$ = [[to]] 90°) to the longitudinal axis 290 or positioned

at an angle +β or an angle -β (in which 0° < +β < 90° or 0° < –β < 90°) from the centerline 302A, 302B of the gas conduit 250A, 250B to the longitudinal axis 290. Therefore, the gas conduit 250A, 250B may be positioned horizontally normal to the longitudinal axis 290 as shown in Figure 3, may be angled downwardly at an angle +β, or may be angled upwardly at an angle –β to provide a gas flow toward the walls of the expanding channel 234 rather than directly downward towards the substrate 210 which helps reduce the likelihood of blowing off reactants absorbed on the surface of the substrate 210. In addition, the diameter of the gas conduits 250A, 250B may be increasing from the delivery lines 243A, 243B of the valves 242A, 242B to the gas inlet 236A, 236B to help reduce the velocity of the gas flow prior to its entry into the expanding channel 234. For example, the gas conduits 250A, 250B may comprise an inner diameter which is gradually increasing or may comprise a plurality of connected conduits having increasing inner diameters.

[0038] Referring to Figure 1, the expanding channel 234 comprises a channel which has an inner diameter which increases from an upper portion 237 to a lower portion 235 of the expanding channel 234 adjacent the bottom surface 260 of the chamber lid 232. In one specific embodiment, the inner diameter of the expanding channel 234 for a chamber adapted to process 200 mm diameter substrates is between about 0.2 inches and about 1.0 inches, ~~more~~ preferably between about 0.3 inches and about 0.9 inches, and more preferably between 0.3 inches and about 0.5 inches at the upper portion 237 of the expanding channel 234 and between about 0.5 inches and about 3.0 inches, preferably between about 0.75 inches and about 2.5 inches, and more preferably between about 1.1 inches and about 2.0 inches at the lower portion 235 of the expanding channel 234. In another specific embodiment, the inner diameter of the expanding channel 234 for a chamber adapted to process 300 mm diameter substrates is between about 0.2 inches and about 1.0 inches, ~~more~~ preferably between about 0.3 inches and about 0.9 inches, and more preferably between 0.3 inches and about 0.5 inches at the upper portion 237 of the expanding channel 234 and between about 0.5 inches and about 3.0 inches, preferably between about 0.75 inches and about 2.5 inches, and more preferably between about 1.2 inches and about 2.2 inches at the

lower portion 235 of the expanding channel 234 ~~for a 300 mm substrate~~. In general, the above dimension apply to an expanding channel adapted to provide a total gas flow of between about 500 sccm and about 3,000 sccm. In other specific embodiments, the dimension may be altered to accommodate a certain gas flow therethough. In general, a larger gas flow will require a larger diameter expanding channel. In one embodiment, the expanding channel 234 may be shaped as a truncated cone (including shapes resembling a truncated cone). Whether a gas is provided toward the walls of the expanding channel 234 or directly downward towards the substrate 210, the velocity of the gas flow decreases as the gas flow travels through the expanding channel 234 due to the expansion of the gas. The reduction of the velocity of the gas flow helps reduce the likelihood the gas flow will blow off reactants absorbed on the surface of the substrate 210.

[0039] Not wishing to be bound by theory, it is believed that the diameter of the expanding channel 234, which is gradually increasing from the upper portion 237 to the lower portion 235 of the expanding channel 234, allows less of an adiabatic expansion of a gas through the expanding channel 234 which helps to control the temperature of the gas. For instance, a sudden adiabatic expansion of a gas delivered through the gas inlet 236A, 236B into the expanding channel 234 may result in a drop in the temperature of the gas which may cause condensation of the gas and formation of ~~particles~~ droplets. On the other hand, a gradually expanding channel 234 according to embodiments of the present invention is believed to provide less of an adiabatic expansion of a gas. Therefore, more heat may be transferred to or from the gas, and, thus, the temperature of the gas may be more easily controlled by controlling the surrounding temperature of the gas (i.e., controlling the temperature of the chamber lid 232). The gradually expanding channel 234 may comprise one or more tapered inner surfaces, such as a tapered straight surface, a concave surface, a convex surface, or combinations thereof or may comprise sections of one or more tapered inner surfaces (i.e. a portion tapered and a portion non-tapered).

[0040] In one embodiment, the gas inlets 236A, 236B are located adjacent the upper portion 237 of the expanding channel 234. In other embodiments, one or more gas inlets 236A, 236B may be located along the length of the expanding channel 234 between the upper portion 237 and the lower portion 235.

[0041] Figure 2 is a top cross-sectional view of one embodiment of the expanding section 234 of the chamber lid 232 of Figure 1. Each gas conduit 250A, 250B may be positioned at an angle α from the center line ~~302~~ 302A, 302B of the gas conduit 250A, 250B and from a radius line 304 from the center of the expanding channel 234. Entry of a gas through the gas conduit 250A, 250B preferably positioned at an angle α (i.e., when α > 0 °) causes the gas to flow in a circular direction as shown by arrow 310A (or 310B). Providing gas at an angle α as opposed to directly straight-on to the walls of the expanding channel (i.e. when α=0°) helps to provide a more laminar flow through the expanding channel 234 rather than a turbulent flow. It is believed that a laminar flow through the expanding channel 234 results in an improved purging of the inner surface of the expanding channel 234 and other surfaces of the chamber lid 232. In comparison, a turbulent flow may not uniformly flow across the inner surface of the expanding channel 234 and other surfaces and may contain dead spots or stagnant spots in which there is no gas flow. In one aspect, the gas conduits 250A, 250B and the corresponding gas inlets 236A, 236B are spaced out from each other and direct a flow in the same circular direction (i.e., clockwise or counter-clockwise).

[0042] Not wishing to be bound by theory, Figure 3 is a cross-sectional view of the expanding channel 234 of a chamber lid 232 showing simplified representations of two gas flows therethrough. Although the exact flow pattern through the expanding channel 234 is not known, it is believed that the circular flow 310 (Figure ~~3~~ 2) may travel as a "vortex," "helix," or "spiral" flow ~~402A, 402B~~ through the expanding channel 234 as shown by arrows 402A, 402B (hereinafter "vortex" flow 402). As shown in Figure 3, the circular flow may be provided in a "processing region" as opposed to in a compartment separated from the substrate 210. In one aspect, the vortex flow may help to establish

a more efficient purge of the expanding channel 234 due to the sweeping action of the vortex flow pattern across the inner surface of the expanding channel 234.

[0043] In one embodiment, the distance 410 between the gas inlets 236A, 236B and the substrate 210 is made ~~far~~ long enough that the "vortex" flow 402 dissipates to a downwardly flow as shown by arrows 404 as a spiral flow across the surface of the substrate 210 may not be desirable. It is believed that the "vortex" flow 402 and the downwardly flow 404 proceeds in a laminar manner efficiently purging the surface of the chamber lid 232 and the substrate 210. In one specific embodiment the distance 410 between the upper portion 237 of the expanding channel 234 and the substrate 210 is about 1.0 inches or more, ~~more~~ preferably about 2.0 inches or more. In one specific embodiment, the upper limit of the distance 410 is dictated by practical limitations. For example, if the distance 410 is very long, then the residence time of a gas traveling though the expanding channel 234 would be long, then the time for a gas to deposit onto the substrate would be long, and then throughput would be low. In addition, if distance 410 is very long, manufacturing of the expanding channel 234 would be difficult. In general, the upper limit of distance 410 may be 3 inches ~~or more~~ for a chamber adapted to process 200 mm diameter substrates or 5 inches ~~or more~~ for a chamber adapted to process 300 mm diameter substrates.

[0045] Not wishing to be bound by theory, Figure 4 is schematic view illustrating the flow of a gas at two different positions 502, 504 between the bottom surface 260 of the chamber lid 232 and the surface of a substrate 210. The velocity of the gas at a certain position is theoretically determined by the equation below:

(1) $Q/A = V$

In which, "Q" is the flow of the gas, "A" is the area of the flow section, and "V" is the velocity of the gas. The velocity of the gas is inversely proportional to the area "A" of the flow section ($H \times 2\pi R$), in which "H" is the height of the flow section and "$2\pi R$" is the circumference of the flow section having a radius "R". In other words, the velocity of a gas is inversely proportional to the height "H" of the flow section and the radius "R" of the flow section.

[0046] Comparing the velocity of the flow section at position 502 and position 504, assuming that the flow "Q" of the gas at all positions between the bottom surface 260 of the chamber lid 232 and the surface of the substrate 210 is equal, the velocity of the gas may be theoretically made equal by having the area "A" of the flow sections equal. For the area of flow sections at position 502 and position 504 to be equal, the height H_1 at position 502 must be greater than the height H_2 at position 504.

[0047] In one aspect, the bottom surface 260 is downwardly sloping to help reduce the variation in the velocity of the gases as it travels between the bottom surface 260 of the chamber lid 232 and the substrate 210 to help provide uniform exposure of the surface of the substrate 210 to a reactant gas. In one embodiment, the ratio of the maximum area of the flow section over the minimum area of the flow section between a downwardly sloping bottom surface 260 of the chamber lid 232 and the surface of the substrate 210 is ~~preferably~~ less than about 2, ~~more~~ preferably less than about 1.5, more preferably less than about 1.3, and most preferably about 1.

[0048] Not wishing to be bound by theory, it is believed that a gas flow traveling at a more uniform velocity across the surface of the substrate 210 helps provide a more uniform deposition of the gas on the substrate 210. It is believed that the velocity of the gas is directly proportional to the concentration of the gas which is in turn directly proportional to the deposition rate of the gas on the substrate 210 surface. Thus, a higher velocity of a gas at a first area of the surface of the substrate 210 versus a second area of the surface of the substrate 210 is believed to provide a higher deposition of the gas on the first area. It is believed that a chamber lid 232 having a downwardly sloping bottom surface 260 provides for more uniform deposition of the gas across the surface of the substrate 210 because the downwardly sloping bottom surface 260 provides a more uniform velocity and, thus, a more uniform concentration of the gas across the surface of the substrate 210.

[0049] Referring to Figure 1, the chamber lid 232 may have a choke 262 at a peripheral portion of the chamber lid 232 adjacent the periphery of the substrate 210. The choke 262, when the chamber lid 232 is assembled to form a processing zone around the substrate 210, comprises any member restricting the flow of gas therethrough at an area adjacent the periphery of the substrate 210. Figure 9A is a schematic cross-sectional view of one embodiment of the choke 262. In this embodiment, the choke 262 comprises a circumferential lateral portion 267. In one aspect, the purge ring 222 may be adapted to direct a purge gas toward the lateral portion 267 of the choke 262. Figure 9B is a schematic cross-sectional view of another embodiment of the choke 262. In this embodiment, the choke 262 comprises a circumferential downwardly extending protrusion 268. In one aspect, the purge ring 222 may be adapted to direct a purge gas toward the circumferential downwardly extending protrusion 268. In one specific embodiment, the thickness of the downwardly extending protrusion 268 is between about 0.01 inches and about 1.0 inch, ~~more~~ preferably between 0.01 inches and 0.5 inches.

[0050] In one specific embodiment, the spacing between the choke 262 and the substrate support 212 is between about 0.04 inches and about 2.0 inches, and preferably between 0.04 inches and about 0.2 inches. The spacing may vary depending on the gases being delivered and the process conditions during deposition. The choke 262 helps provide a more uniform pressure distribution within the volume or a reaction zone 264 defined between the chamber lid 232 and the substrate 210 by isolating the reaction zone 264 from the non-uniform pressure distribution of the pumping zone 266 (Figure 1).

[0051] Referring to Figure 1, in one aspect, since the reaction zone 264 is isolated from the pumping zone 266, a reactant gas or purge gas needs only adequately fill the reaction zone 264 to ensure sufficient exposure of the substrate 210 to the reactant gas or purge gas. In conventional chemical vapor deposition, prior art chambers are required to provide a combined flow of reactants simultaneously and uniformly to the entire surface of the substrate in order to ensure that the co-reaction of the reactants

occurs uniformly across the surface of the substrate 210. In atomic layer deposition, the present chamber 200 sequentially introduces reactants to the substrate 210 surface to provide absorption of alternating thin layers of the reactants onto the surface of the substrate 210. As a consequence, atomic layer deposition does not require a flow of a reactant which reaches the surface of the substrate 210 simultaneously. Instead, a flow of a reactant needs to be provided in an amount which is sufficient to absorb a thin layer of the reactant on the surface of the substrate 210.

[0054] The chamber lid 232 may include cooling elements and/or heating elements depending on the particular gas being delivered therethrough. Controlling the temperature of the chamber lid 232 may be used to prevent gas decomposition, deposition, or condensation on the chamber lid 232. For example, water channels (not shown) may be formed in the chamber lid 232 to cool the chamber lid 232. In another example, heating elements (not shown) may be embedded or may surround components of the chamber lid 232 to heat the chamber lid 232. In one embodiment, components of the chamber lid 232 may be individually heated or cooled. For example, referring to Figure 1, the chamber lid 232 may comprise a chamber plate portion 270 and a cap portion 272 in which the chamber plate portion 270 and the cap portion 272 form the expanding channel 234. The cap portion 272 may be maintained at one temperature range and the chamber ~~lid~~ plate portion 270 may be maintained at another temperature range. For example, the cap 272 may be heated by being wrapped in heater tape or by using another heating device to prevent condensation of reactant gases and the chamber plate portion 270 may be maintained at ambient temperature. In another example, the cap 272 may be heated and the chamber plate portion 270 may be cooled with water channels formed therethrough to prevent thermal decomposition of reactant gases on the chamber plate portion 270.

[0055] The chamber lid 232 may be made of stainless steel, aluminum, nickel-plated aluminum, nickel, or other suitable materials compatible with the processing to be performed. In one embodiment, the cap portion 272 comprises stainless ~~steal~~ steel and the chamber plate portion 270 comprises aluminum. In one embodiment, the optional

additional plate disposed therebetween comprises stainless ~~steal~~ steel. In one embodiment, the expanding channel 234 and the bottom surface 260 of the chamber lid 232 may comprise a mirror polished surface to help produce a laminar flow of a gas along the expanding channel 234 and the bottom surface 260 of the chamber lid 232. In another embodiment, the inner surface of the gas conduits 250A, 250B may be electropolished to help produce a laminar flow of a gas therethrough.

[0059] Chamber 200 as illustrated in Figures 1-4 has been described herein as having a combination of features. In one aspect, chamber 200 provides a reaction zone 264 comprising a small volume in compared to a conventional CVD chamber. The chamber 200 requires a smaller amount of a gas, such as a reactant gas or a purge gas, to fill the reaction zone 264 for a particular process. In another aspect, chamber 200 provides a chamber lid 232 having a downwardly sloping or funnel shaped bottom surface 260 to reduce the variation in the velocity profile of a gas flow traveling between the bottom surface of the chamber lid 232 and a substrate 210 In still another aspect, the chamber 200 provides an expanding channel 234 to reduce the velocity of a gas flow introduced therethrough. In still another aspect, the chamber 200 provides gas conduits at an angle α from the center of the expanding channel 234. The chamber 200 provides other features as described elsewhere herein. Other embodiments of a chamber adapted for atomic layer deposition incorporate one or more of these features.

[0060] For example, Figure 7 shows another embodiment of a chamber 800 including a gas delivery apparatus 830 comprising a chamber lid 832 which provides a reaction 864 zone comprising a small volume and which provides an expanding channel 834. Some components of the chamber 800 are the same or similar to those described with reference to chamber 200 of Figure 1, described above. Accordingly, like numbers have been used where appropriate. The chamber lid 832 comprises a bottom surface 860 that is substantially flat. In one embodiment, the spacing between the choke 262 and the substrate support ~~210~~ 212 is between about 0.04 inches and about 2.0 inches, ~~more~~ preferably between about 0.04 inches and about 0.2 inches.

[0061] In another example, Figure 8 shows another embodiment of a chamber 900 including a gas delivery apparatus 930 comprising a chamber lid 932 which provides a reaction zone 964 comprising a small volume and which provides a downwardly sloping or funnel shaped bottom surface 960. Some components of the chamber 900 are the same or similar to those described with reference to chamber 200 of Figure 1, described above. Accordingly, like numbers have been used where appropriate. Gas sources 937 are coupled to the passageway 933 through one or more valves 941. In one aspect, the passageway 933 ~~comprising~~ comprises a long length to reduce the likelihood that a gas introduced through valve 941 will blow off reactants absorbed on the surface of the substrate 210.

[0062] The gas delivery apparatuses 230, 830, 930 of Figures 1-8 ~~has~~ have been described above as comprising chamber lids 232, 832, 932 which act as the lid of the chamber body 202. Other embodiments of the chamber lids 232, 832, 932 comprises any covering member disposed over the substrate support 212 delineating a reaction zone 264, 864, 964 which lowers the volume in which a gas must flow during substrate processing. In other embodiments, instead of or in conjunction with the substrate support 212, the chamber lid 232, 832, 932 may be adapted to move up and down to adjust the volume of the reaction zone 264, 864, 964.

[0063] The gas delivery apparatus 230 of Figure 1 has been described as including two pairs of valves 242A/252A, 242B/252B coupled to a reactant gas source 238, 239 and a purge gas source 240. In other embodiments, the gas delivery apparatus 230 may comprise one or more valves coupled to a single or a plurality of gas sources in a variety of configurations. Figures 1-3 show a chamber 200 adapted to provide two gas flows together or separately from two gas inlets 236A, 236B utilizing two pairs of valves 242A/252A, 242B/252B. Figure 5 is a top cross-sectional view of another embodiment of ~~the~~ an expanding channel 634 of the chamber lid 232 which is adapted to receive a single gas flow through one gas inlet 636 from one gas conduit 650 coupled to a single or a plurality of valves. The gas conduit 650 may be positioned at an angle α from the center line 602 of the gas conduit 650 and from a radius line 604 from the center of the

expanding channel 634. The gas conduit 650 positioned at an angle α (i.e., when $\alpha > 0$ °) causes a gas to flow in a circular direction as shown by arrow 610. Figure 6 is a top cross-sectional view of another embodiment of ~~the~~ an expanding channel 734 of the chamber lid 232 which is adapted to receive three gas flows together, partially together (i.e. two of three gas flows together), or separately through three gas inlets 736A, 736B, 736C from three gas conduits 750A, 750B, 750C in which each conduit is coupled to a single or a plurality of valves. The gas conduits 750A, 750B, 750C may be positioned at an angle α from the center line 702 of the gas conduits 750A, 750B, 750C and from a radius line 704 from the center of the expanding channel 734. The gas conduits 750A, 750B, 750C positioned at an angle α (i.e., when $\alpha > 0$ °) causes a gas to flow in a circular direction as shown by arrows 710.

[0068] Other examples of tantalum containing compounds, include, but are not limited to, other organo-metallic precursors or derivatives thereof, such as pentaethylmethylamino-tantalum (PEMAT; $Ta[N(C_2H_5CH_3)_2]_5$), pentadiethylamino-tantalum (PDEAT; $Ta(NEt_2)_5$,), and any and all derivatives of PEMAT, PDEAT, or PDMAT. Other tantalum containing compounds include without limitation TBTDET ($Ta(NEt_2)_3NC_4H_9$ or $C_{16}H_{39}N_4Ta$) and tantalum halides, for example TaX_5 where X is fluorine (F), bromine (Br) or chlorine (Cl), and/or derivatives thereof. Other nitrogen containing compounds may be used which include, but are not limited to, N_xH_y with x and y being integers (*e.g.*, hydrazine (N_2H_4)), dimethyl hydrazine ~~((CH3)2N2H2)~~ $((CH_3)_2N_2H_2)$, t-butylhydrazine ($C_4H_9N_2H_3$) phenylhydrazine ($C_6H_5N_2H_3$), other hydrazine derivatives, a nitrogen plasma source (*e.g.,* N_2, N_2/H_2, NH_3, or a N_2H_4 plasma), 2,2'-azoisobutane ($(CH_3)_6C_2N_2$), ethylazide ($C_2H_5N_3$), and other suitable gases. Other examples of purge gases include, but are not limited to, helium (He), nitrogen (N_2), hydrogen (H_2), other gases, and combinations thereof.

[0070] The time duration for each pulse of the tantalum containing compound, the time duration for each pulse of the nitrogen containing compound, and the duration of the purge gas flow between pulses of the reactants are variable and depend on the volume capacity of a deposition chamber employed as well as a vacuum system coupled

thereto. For example, (1) a lower chamber pressure of a gas will require a longer pulse time; (2) a lower gas flow rate will require a longer time for chamber pressure to rise and stabilize requiring a longer pulse time; and (3) a large-volume chamber will take longer to fill, longer for chamber pressure to stabilize thus requiring a longer pulse time. Similarly, time between each pulse is also variable and depends on volume capacity of the process chamber as well as the vacuum system coupled thereto. In general, the time duration of a pulse of the tantalum containing compound or the nitrogen containing compound should be long enough for absorption of a monolayer of the compound. In one aspect, a pulse of a tantalum containing compound may still be in the chamber when a pulse of a nitrogen containing compound enters. In general, the duration of the purge gas and/or pump evacuation should be long enough to prevent the pulses of the tantalum containing compound and the nitrogen containing compound from mixing together in the reaction zone.